Q STRUCTURE AND INNER-SHELL VACANCIES IN NEON-NEON AND KRYPTON-KRYPTON COLLISIONS*

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In close encounters of the systems Ne-Ne, Ne^+-Ne, and Ne^{++}-Ne, electrons of 750-eV energy are produced. The numbers of such fast electrons are found to depend upon the charge state of the incident particle (0, +1, or +2) in the ratio of 0.6, 1.0, and 2.0, respectively. This agrees in part with a prediction by Lichten. In Kr^+-Kr collisions, there is a sudden change in the average number of electrons lost for 9° scattering at 25-keV incident energy.

Previous studies have shown that 200-keV Ne^+ ions incident upon neon gas cause ejection of 750-eV electrons.[1,2] Coincidence measurements[3] at the same energy showed that there are two distinct values of the average inelastic energy loss Q, one at 710 eV and the other at 1550 eV, for the reaction

$$Ne^+ + Ne \rightarrow Ne^{5+} + Ne^{3+} + 7e \qquad (1)$$

with the scattering angle θ set at 8°. These two results suggested[3] that a K-shell vacancy can be created by such collisions.

Lichten[4] drew energy-level diagrams for the Ne-Ne system and made a qualitative explanation in terms of a K-shell promotion mechanism. He predicted that the number of fast electrons should be dependent upon the charge of the incident neon, in the ratio of 0, 1, and 2 for Ne, Ne^+, and Ne^{++}, respectively.

Our experiment is performed to check Lichten's prediction. Here Ne, Ne^+, and Ne^{++} of 200-keV energy are sent through neon gas. Previously described apparatus and procedures[5] are used to make a (noncoincident) energy analysis of the resulting fast electrons and later to determine (with coincidence methods) the Q values at 10° scattering.

Figure 1(a) shows the electron energy distributions, normalized to the same incident-particle flux per unit target gas density, for the three different cases. The data are taken with electrons scattered at 95° to the incident direction, this angle chosen to prevent scattered neons from reaching the detector and to limit Doppler broadening (see Ref. 1). The number of electrons are approximately in the ratio of 0.6, 1.0, and 2.0 for the Ne, Ne^+, and Ne^{++} cases, respectively.

This agrees with Lichten's[4] prediction for the ratio in the Ne^{++} and Ne^+ cases. Lichten predicts, on the other hand, that no fast electrons should arise when the incident beam is neutral neon in the ground state. Figure 1(a) shows, however, that such electrons are observed for the neutral-beam case. One might suppose that the electrons observed arise from incident neons which are not in the ground state. Experimental evidence for excitation in the neutral beam is incomplete. This beam is produced by passing singly ionized neon particles through a charge-exchange chamber filled first with neon and later with krypton. The results were the same in either case. However, no direct analysis is made of the excitation condition of the neutral beam. These incident neutrals, as well as the Ne^+ and Ne^{++} beams from the rf ion source, may be partially excited. Russek[6] has suggested that even if both neons were initially in the ground state, the interactions among the outer electrons during the first part of the collision may create excitations which then allow K-shell promotions to occur later in the collision.

Coincidence measurements for the 5, 3 reaction [similar to Eq. (1)] are made with 200-keV beams of Ne, Ne^+, and Ne^{++} with the scattered-ion detector set at $\theta = 10°$. The resulting Q pro-

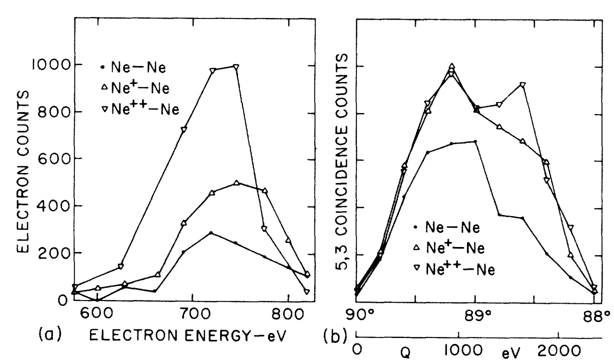

FIG. 1. (a) Electron energy distributions for 200-keV Ne, Ne^+, and Ne^{++} incident upon neon gas, normalized to the same incident particle intensity per unit target-gas density. (b) Inelastic energy profiles for Ne-Ne, Ne^+-Ne, and Ne^{++}-Ne collisions which result in Ne^{5+} and Ne^{3+} collision products. These data are for 200-keV energy and 10° scattering.

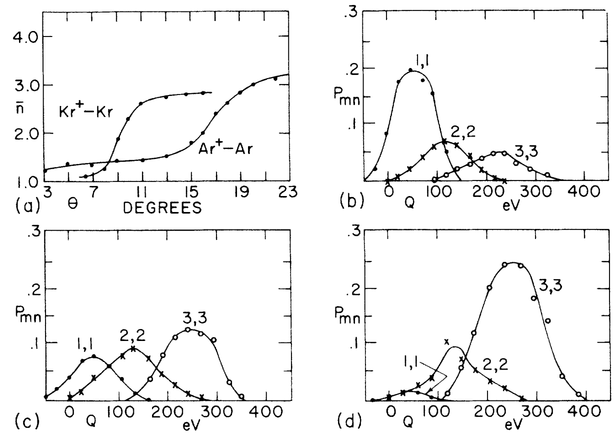

FIG. 2. (a) Average charge state $\bar{n}$ for Kr^+-Kr and Ar^+-Ar collisions at 25 keV as a function of scattering angle θ. (b) Relative charge-state populations after scattering for the Kr^+-Kr collision at 25 keV as a function of inelastic energy Q, for a scattering angle of 8 deg. (c) Same for 9 deg. (d) Same for 10 deg.

files are shown in Fig. 1(b). These are considerably broader than the instrumental resolution, suggesting two unresolved components. From the shapes the high-Q component is largest for the Ne^{++}-Ne case and smallest for the Ne-Ne case. As the higher energy contribution is dependent upon the number of K-shell vacancies, the differences of structure for the three cases are consistent with the relative numbers of fast electrons shown in Fig. 1(a).

The Kr^+-Kr collision is studied to find whether there is Q structure as seen in Ar^+-Ar collisions.[5] Near 25 keV, 9°, some effects are seen which are analogous to those found in Ar^+-Ar in its active region,[5] 25 keV, 16°. Thus the average charge of the scattered particle, plotted versus scattering angle θ [Fig. 2(a)], shows the same sudden rise.[7] Also is this same region, which corresponds to 0.4-Å distance of closest approach, there is a sudden step from 50 to 230 eV in Q.

The corresponding inelastic energy-loss profiles are illustrated in Figs. 2(b)-2(d). These show the relative number of events P_{mn} vs Q value, where the charge state of both particles after collision is specified. At 8° the 1,1 reaction is most prevalent; at 9° and 10° this diminishes while the 3,3 reaction shows the opposite behavior. These individual peaks are widely spaced from each other and change rapidly with angle. The 2,2 peaks are relatively constant at all three angles. Each individual profile does not show the expected triple structure; if present, this is unresolved. Furthermore, no resolved peak of Auger electrons is seen using our apparatus. In these last two respects the Kr^+-Kr data differ from the Ar^+-Ar data.

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[7]This same effect was observed by V. V. Afrosimov, Yu. S. Gordeev, M. N. Panov, and N. V. Fedorenko, Zh. Tekh. Fiz. 36, 123 (1966) [translation: Soviet Phys.—Tech. Phys. 11, 89 (1966)]; see Fig. 4.